AGS Booster Issues

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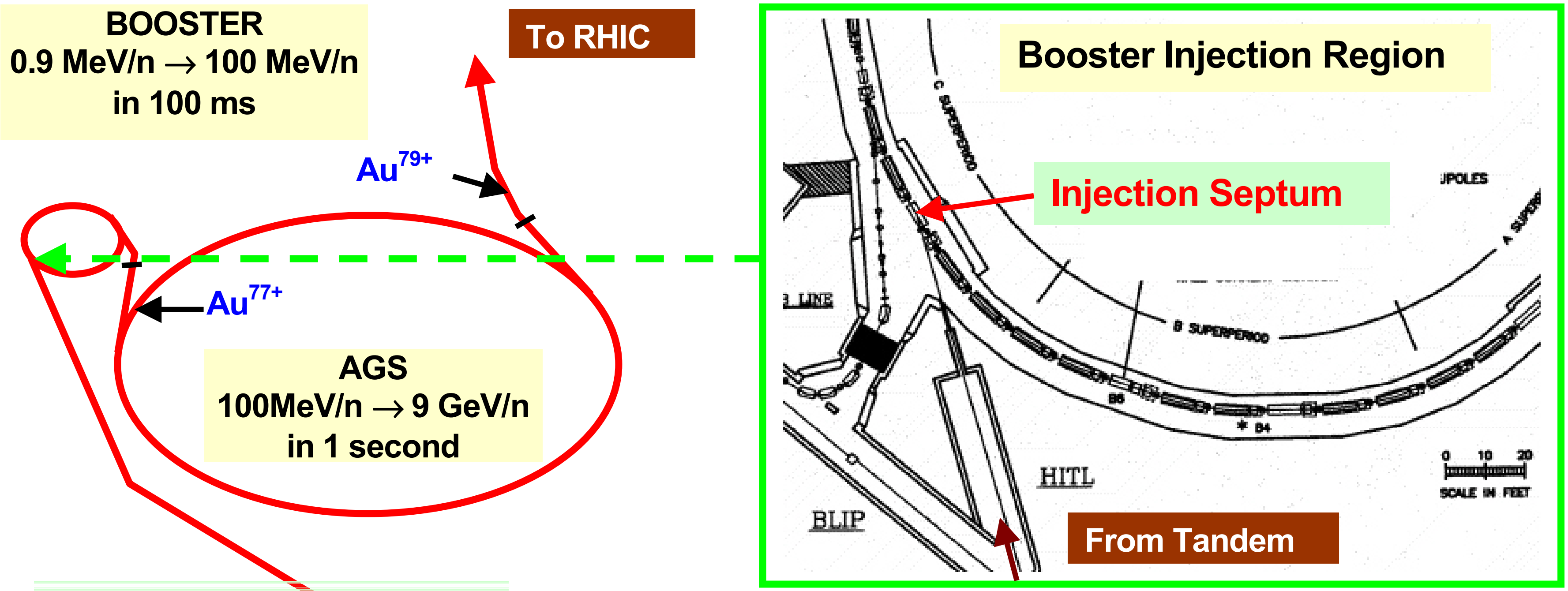
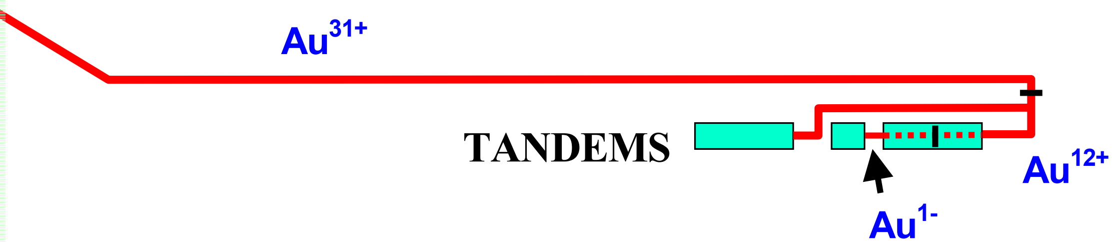
1. RHIC Heavy Ion Injector Complex
2. Beam Loss Mechanism at the Booster Injection
   - Capture loss for Au 31+ ions
3. Vacuum Pressure Measurement at the Booster Injection
   - Transient pressure rise with very high peak
4. Two Tandem Beam Study
   - Dump first beam within 100 ms affects second beam's lifetime
5. Gold Beam Loss Effect in the Booster Ring
   - Beam lifetime decreases after the beam scraping
6. Booster Injection Scrubbing Effect
   - Observed long term beam (sputtering) scrubbing effect
7. Gold Beam Scraping Study at the Injection Septum
   - Secondary electron and ion yield for gold beam loss
8. Tandem Study of Ions Scraping Effect
   - Secondary electron yield with glancing angle incident
9. Comments and Acknowledgment

1. RHIC Heavy Ion Injector Complex



	Int./RHIC bh	Effic.
Tandem	3.8×10^9	
Bstr Inj.	2.2×10^9	58%
Bstr Ext.	1.8×10^9	81%
AGS Inj.	0.9×10^9	50%
AGS Ext.	0.9×10^9	95%
Total		23%
2001 run:	1.2×10^9 / RHIC bh	
2003 run:	1.3×10^9 / RHIC bh	



2. Beam Loss Mechanism at the Booster Injection

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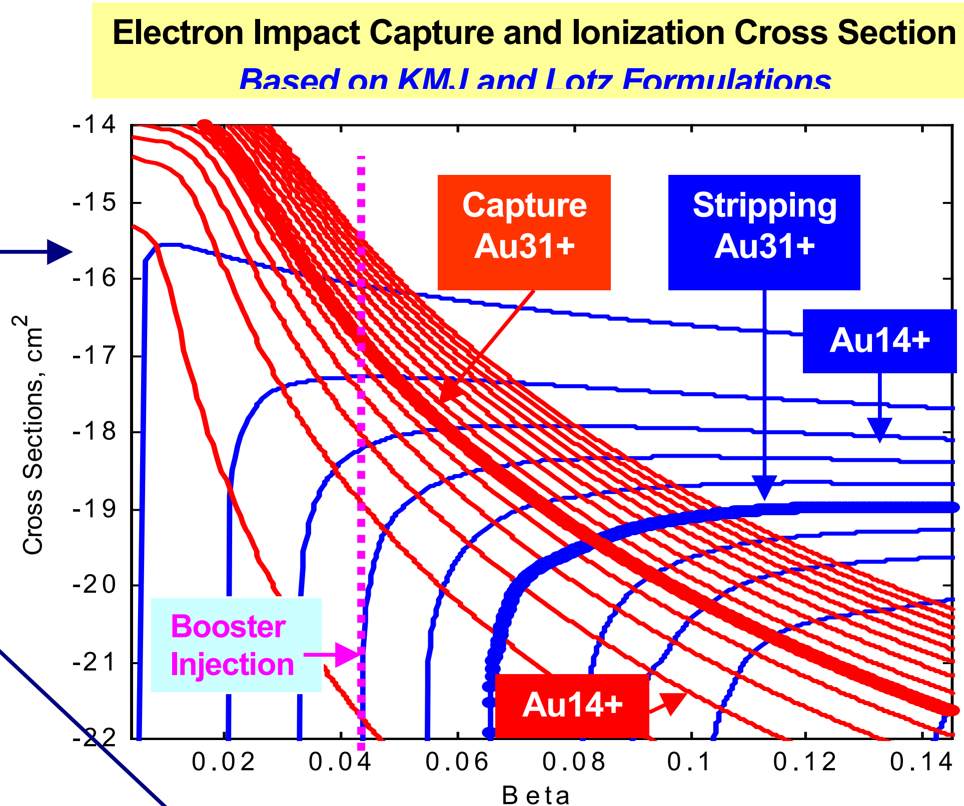
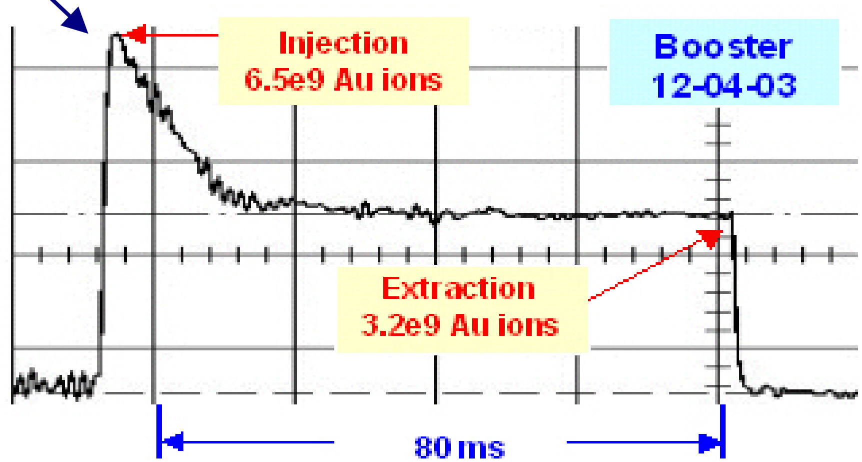
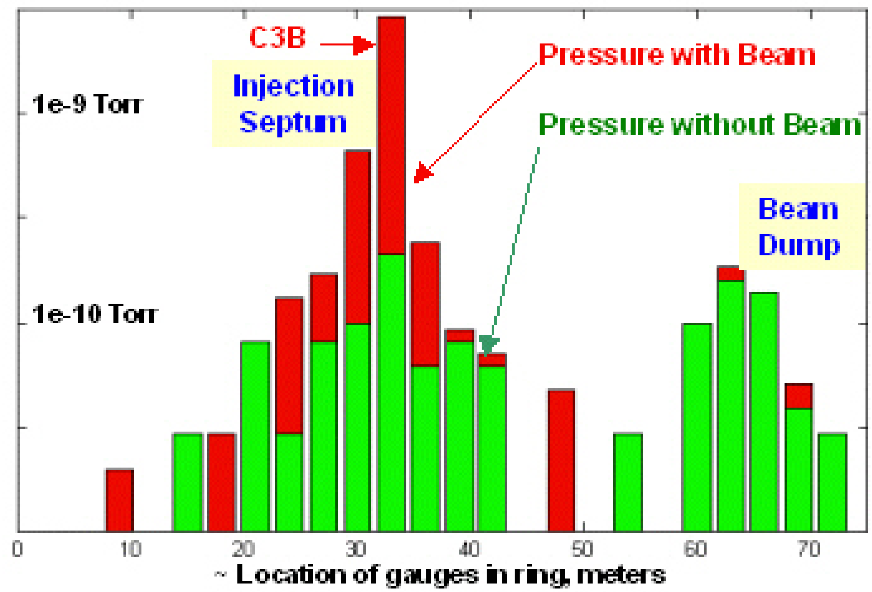
- Beam injected into Booster at 0.9 MeV/n, β = 0.044. Capture cross section (CS) is much larger than the stripping CS.
- In first 20 ms (to β = 0.08), the capture cross section is reduced by a factor of 100, consistent with the observed beam loss pattern.
- For Au 14+ injection, both capture and stripping took effect at the injection, later the stripping loss become dominant.
- Au 14+ beam loss took place in the entire acceleration period, in different loss pattern from Au 31+.
- Injection septum aperture fold correction in Run 4 leads to new high Booster exit, at 3.2e9 Au ions.

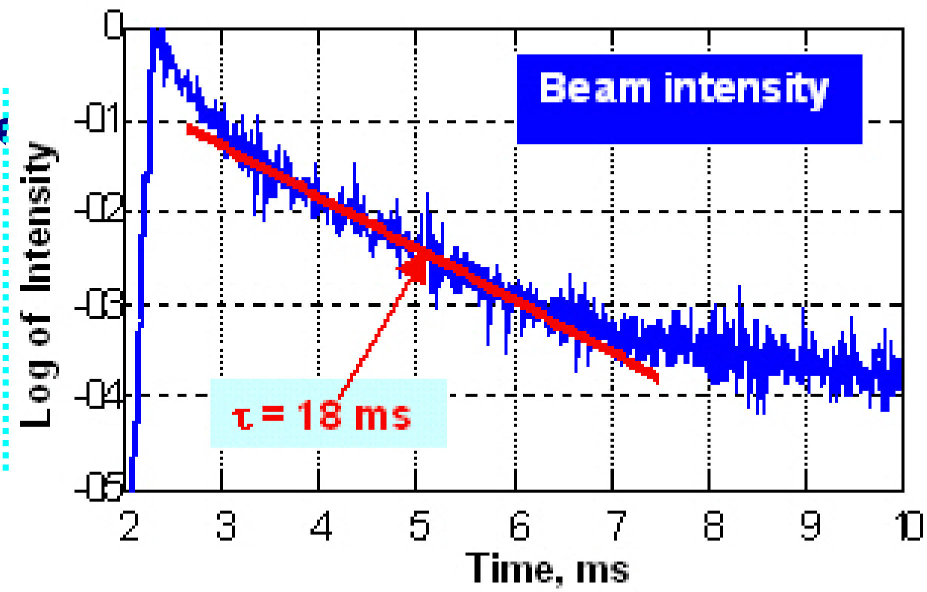




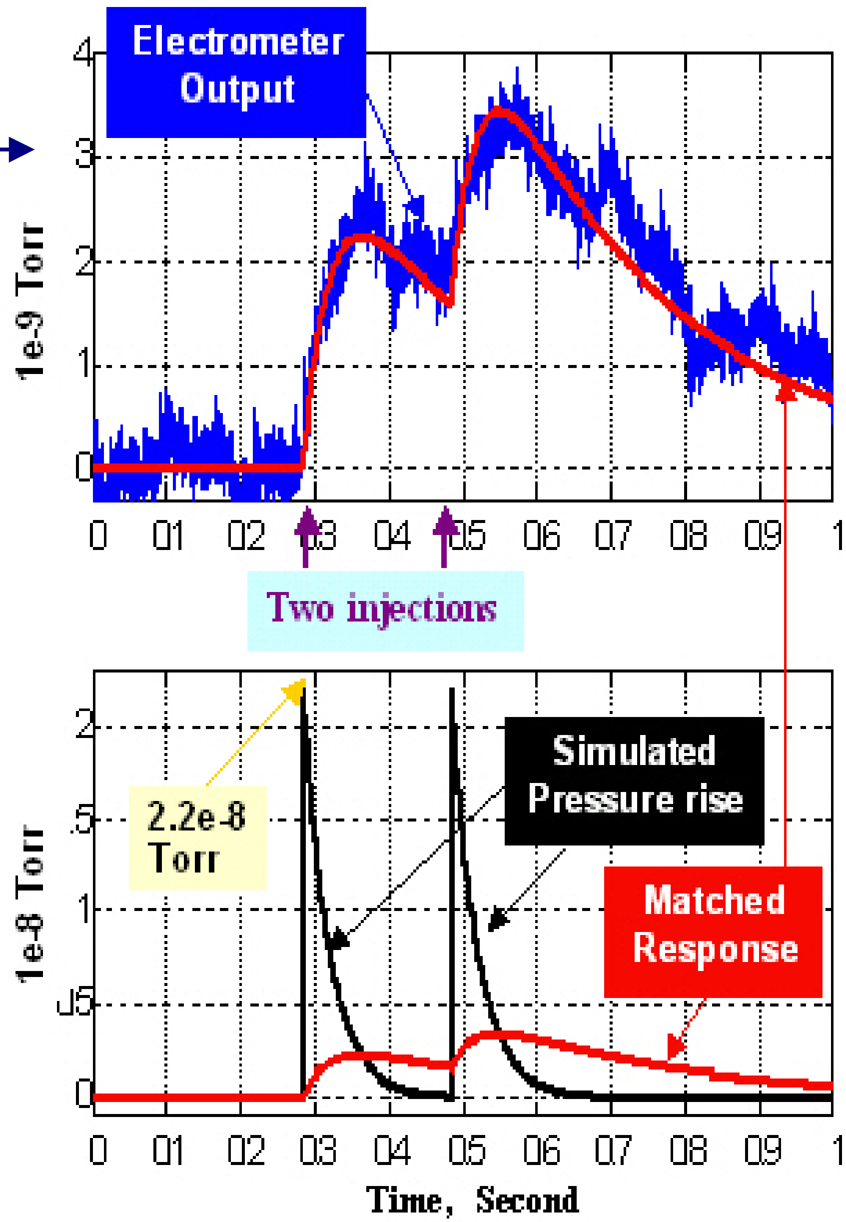
3. Pressure Measurement at the Booster Injection

- Pressure rise at the Booster Au beam injection, highest at the exit of injection septum, C3B.
- Pressure rise spread in about 20 m, with the highest at 3e-9 Torr.
- Taking CO equivalent Au 31+ capture cross section of 2e-16 cm^2, the beam lifetime of 18 ms cannot be explained.
- The pressure rise of 3e-9 Torr is the vacuum gauge measurement averaged every 3 second.
- At 1e-11 Torr level, the ion gauge's signal is in pA's, whereas noise signal may reach nA.
- Vacuum pressure rise at the beam injection was measured by using electrometer to read ion gauge directly.



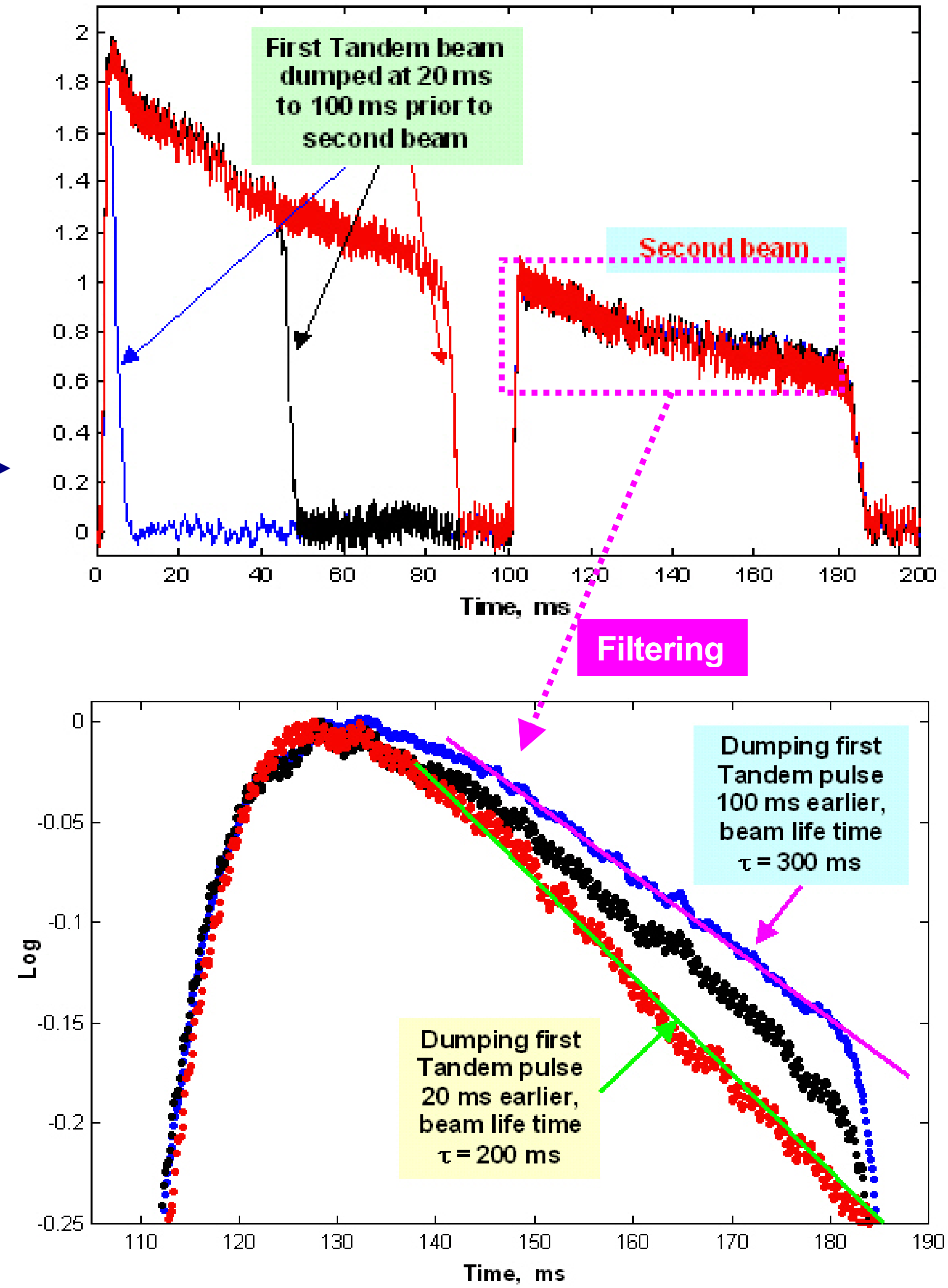


- Simulation using electrometer transfer function shows that with 0.5e9 Au 31+ ions lost, peak pressure rise reaches 2.2e-8 Torr.
- The pressure rise reported was ~ 2e-10 Torr. The real peak pressure rise is a factor of 100 higher.
- Using the simulated pressure rise, at high intensity injection, the beam lifetime is 20 to 50 ms.
- The resulting ion desorption rate is about 100,000.
- Equally important is that pressure decay time constant is 35 ms at low intensity, and 70 ms at high intensity.
- Consistent with the observation: the second Tandem beam injected 200 ms later is usually not affected by the first one.



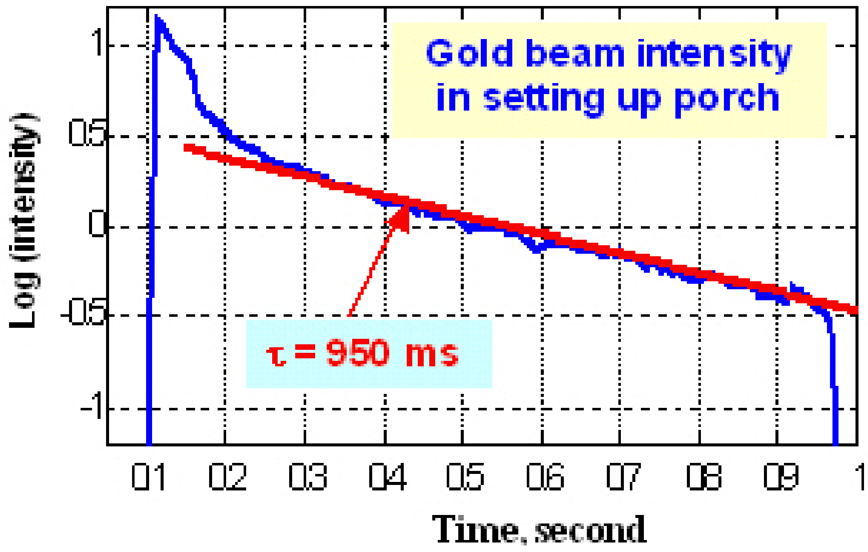
4. Two Tandem Beam Study

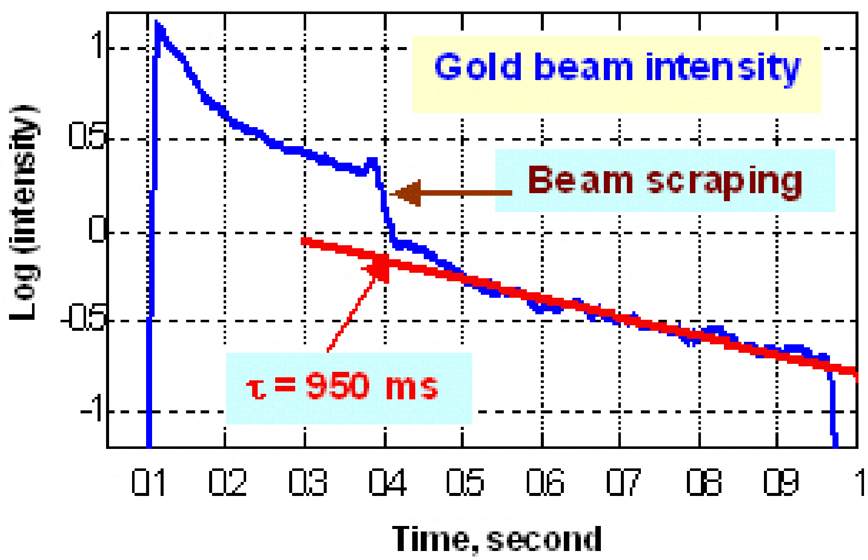
- Using 600 Gauss porch at the Booster, inject two Tandem beams, without ramping.
- Two injections were separated by 100 ms. Dump first beam in Booster in different time to observe the lifetime of the second beam.
- Cesium replenishment at the ion source was insufficient, so direct comparison of two injections was impossible.
- The beam lifetime of the second injection was affected by the first beam dumped < 100 ms earlier, not otherwise.
- This shows that the lost ions in the ring affect the beam lifetime through pressure rise.



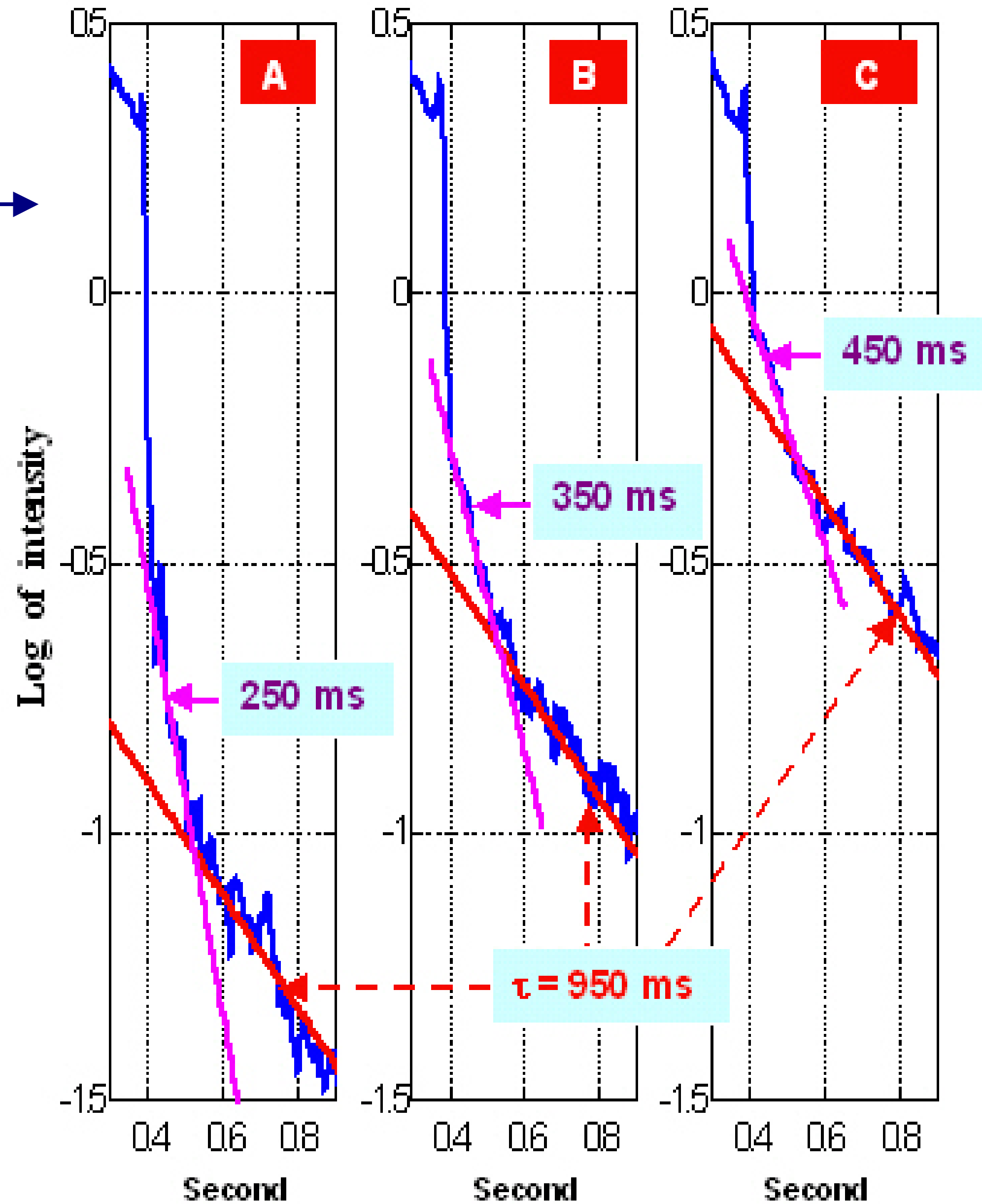
5. Gold Beam Loss Effect in the Booster Ring

- Using a 1 second long, 800 Gauss flat porch
  - Beam energy becomes 1.6 MeV/n, with β = 0.058.
  - Capture cross section is reduced to 1/10.
  - Beam lifetime extended to 950 ms.
- Orbit bumps were used to scrape the beam on the wall, in several locations. Beam intensity was 1e9 Au 31+ ions.
- Beam scraped horizontally and vertically, difference was small.
- Beam lifetime was significantly decreased immediately after the beam scraping, then recovered to 950 ms.
- 3 cases in scraping study.



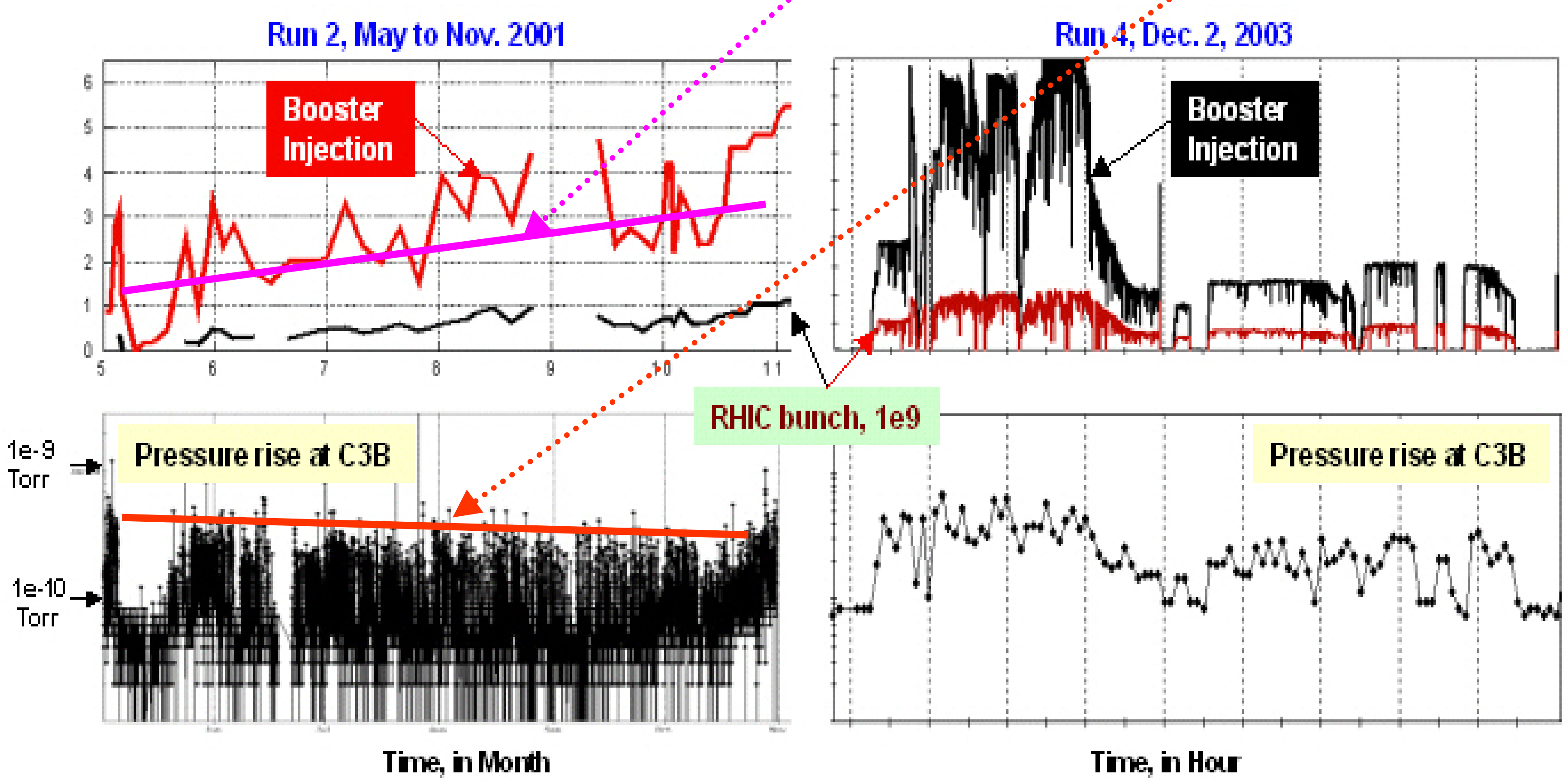


- **Beam loss and beam lifetime immediately followed the scraping in 3 cases are**
  - **A. 3.1e 8 ions, τ = 250 ms.**
  - **B. 2.3e 8 ions, τ = 350 ms.**
  - **C. 1.5e 8 ions, τ = 450 ms.**
- **In all cases, the beam lifetime was affected in a period of 100 ms, consistent with the pressure decay time constant of 35 ms.**
- **Assuming the scraping produced pressure rise in 20 m long pipe, then the pressure rises and the ion desorption rates are**
  - **A. ΔP = 3.4e-8 Torr, η = 1.09e6.**
  - **B. ΔP = 2.5e-8 Torr, η = 1.03e6.**
  - **C. ΔP = 1.9e-8 Torr, η = 1.21e6.**
- **The desorption rates are larger than the ones at the septum study, better beam scraping?**



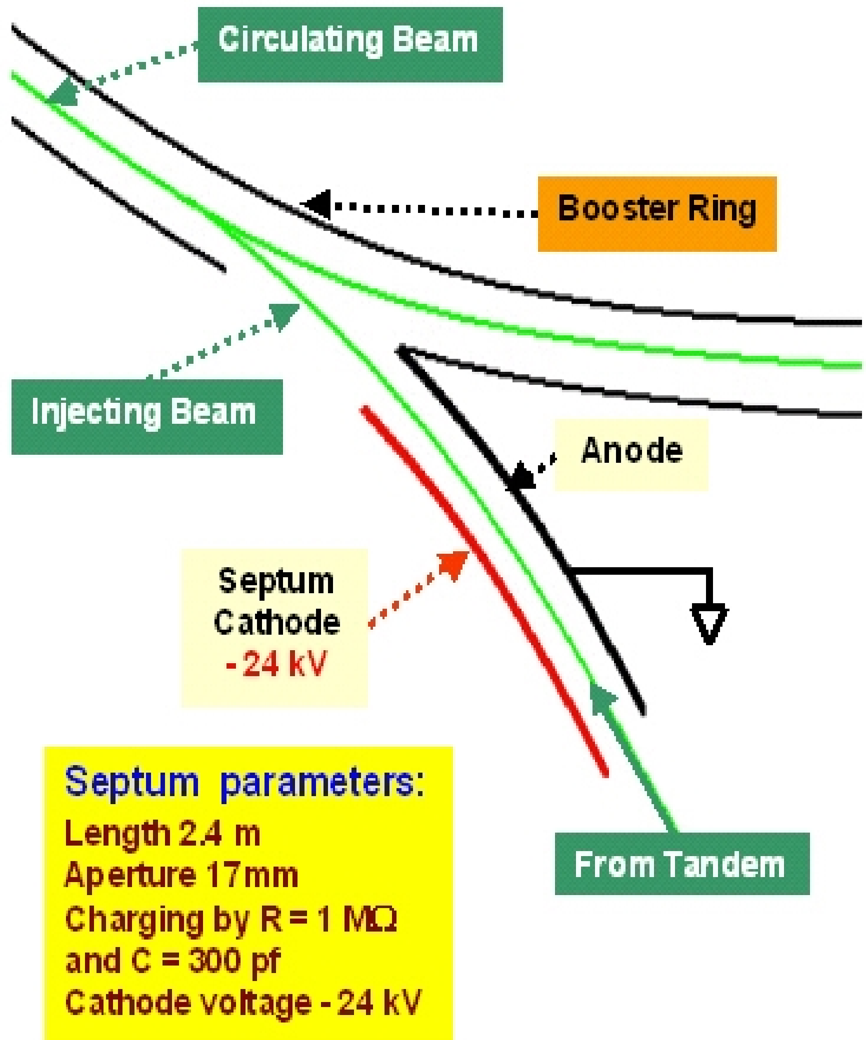
6. Booster Injection Scrubbing Effect

- Booster injection area scrubbing effect has been observed in long terms of time period.
- In Run 2, the Booster injection intensity increased in a period of a few months, the pressure rise at the exit of injection septum decreased.
- In Run 4, after the improvement at the septum aperture, the injection efficiency is already equivalent to the later Run 2 and Run 3.

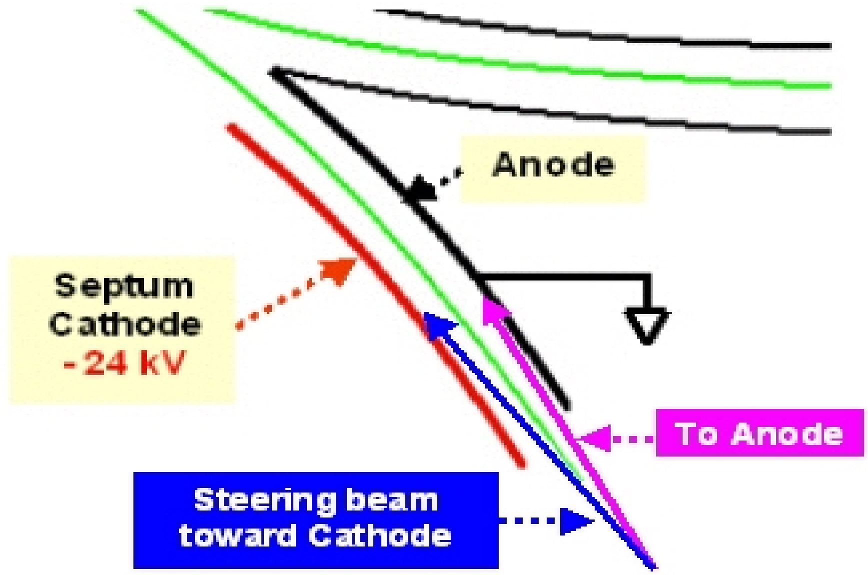


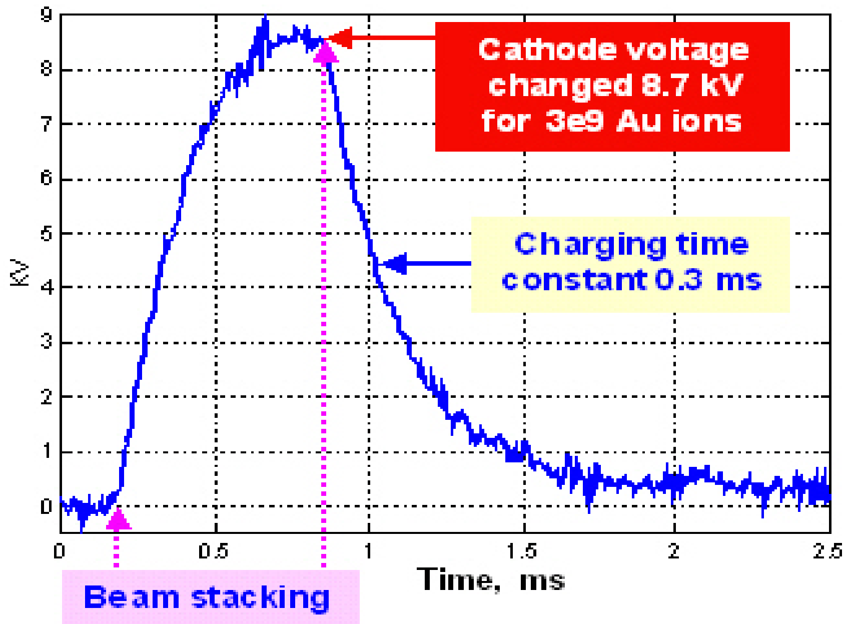
7. Gold Beam Scraping Study at the Injection Septum

- Pressure rise of ~ 20 m long at the beam injection centered at the exit of septum.
- Voltage of septum cathode is used to measure the beam scraping effect. The charging time constant is 0.3 ms, not too small.
- Conventional method is the electron collection.
- Beam FWHM size is 4 mm, and septum aperture is 17 mm.
- SE production depends on
  - Projectile' energy, 0.9 MeV/n is at the production peak.
  - Projectile' charge state, usually a ~ q^2 dependence.
  - Incident angle effect, usually a $1/\cos\theta$ dependence.



- **Secondary electron production**
  - **Steering beam for ~ 1 mm toward the cathode, a 8.7 kV voltage rise was observed.**
  - **The charging time constant is consistent with 0.3 ms.**
  - **With about 0.6e9 ions lost at the scraping, secondary electron yield per lost ion is ~100,000.**
  - **Electron depletion taking effect at the later stacking.**
- **Secondary ion production**
  - **By steering beam toward the anode, >2 kV voltage rise at the cathode was observed.**
  - **Secondary electrons will stay, but secondary ions will go to the cathode.**
  - **Secondary ions (charge) production rate is about 20,000 per lost ion.**

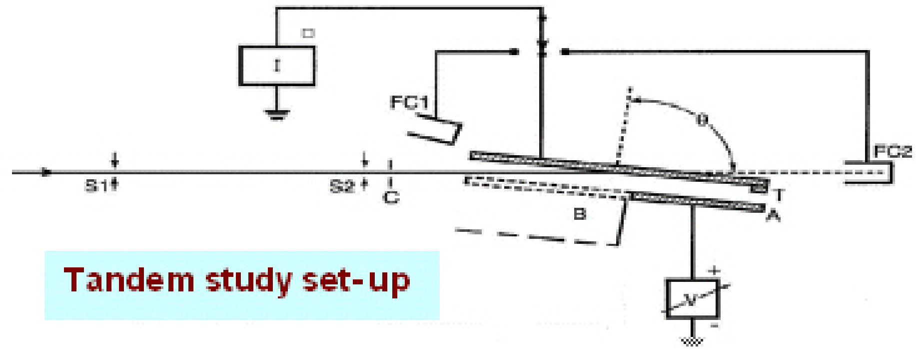




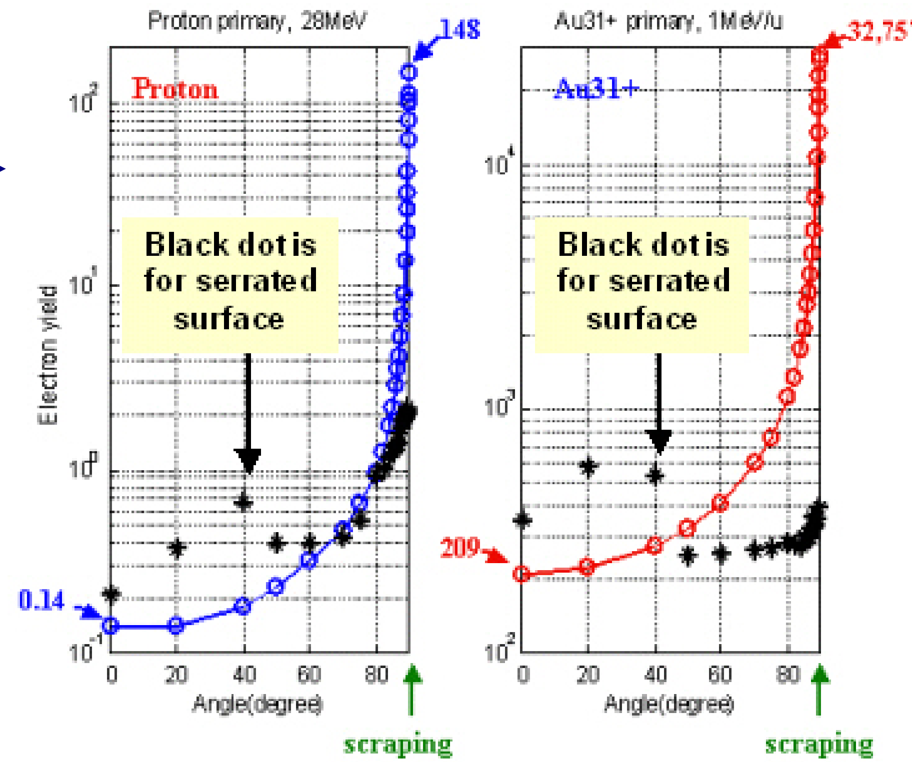
8. Tandem Study of Ions scraping Effect

- The SE production with different incident angles measured at the Tandem, using biased target, rather than to collect electrons,
  - H^+ ions, 28 MeV.
  - O^{8+} ions, 7.9 MeV/n.
  - Au^{31+} ions, 0.9MeV/n.
- Proton, oxygen and gold ions scraping have been measured up to 89.96 degrees.
- SE production rate approximately matches the relation of 1/cosθ.
- Serrated surface significantly reduced SEY at the glancing angle.
- TiN coated surface also studied, the results posed question for the reduction of SEY with ions impact.

A.L. Hanson et al. J. Vac. Sci. Tech. A 19(5), 2001



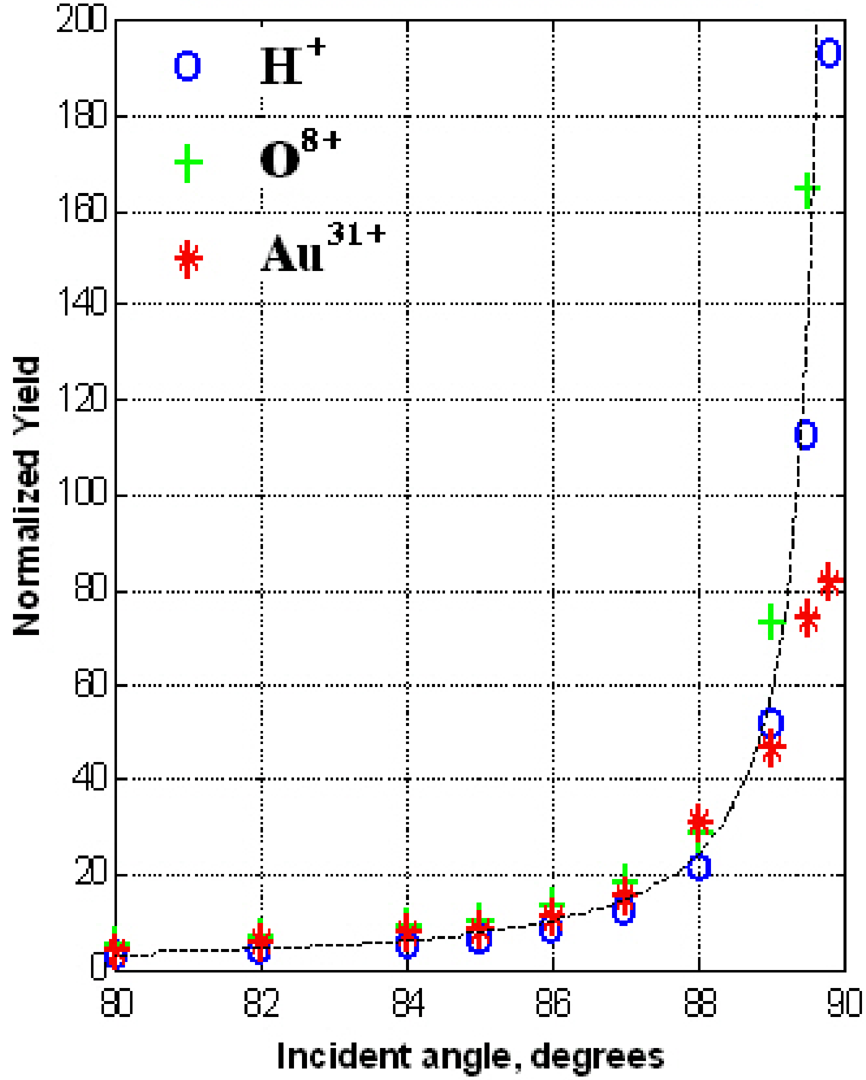
Tandem study set-up



P. Thieberger et al. Physical Review A, V.61, 2000

- Secondary electron yield is normalized by projectile peak production energy, at perpendicular incident angle, and the charge state 1. →
  - Seiler's model is used for the projectile energy dependence, with the peak production energy at 500 eV electrons, or ions with 0.9 MeV/n.
  - The charge state dependence is better matched to $q^{1.6}$.
  - The incident angle dependence is better matched to $1/(\cos\theta)^{1.25}$.
- Proton and oxygen ions yields are matched up to 89.9 degrees, but gold ions SEY started to peak at 89.5 degrees, electron depletion taking effect?

Normalized SE production



9. Comments and Acknowledgment

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Comments

- Many SEY measurements at glancing angles reported maxima at 70° to 85° .
- Some explanations, although bearing truth, may have missed dominant factors.
- If confirmed, Booster and Tandem studies have shown that $1/\cos\theta$ factor extends to very close to 90°.
- The glancing angle ion desorption measurement is more difficult than the SEY measurement.
- Ion desorption measurement is still to be done, if you look at this.

1. Ion beam may be deflected from the target surface by a mechanism similar to planar channeling in crystals. *[Physical Review B]*
2. Close to 90 degree the collision cascades are located so close to surface that they are not fully developed. *[Physical Review B]*
3. Electron depletion. *[NIM B]*

	1981	1991
	Sputtering by Particle Bombardment I	Sputtering by Particle Bombardment III
Yield	1-5	1-20
Energy *max*	5-50 keV	5-500 keV
Angle *max*	to 80 deg.	to 85 deg.

Sputtering by Particle Bombardment, Springer-Verlag

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